OIPE JC41
NOV 0 4 2002
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application Serial No. : 10/056,233 Filed: 12/03/2001

Inventor: GUMMIN Docket No.: 6100

Group Art Unit: 2834 Examiner:

For: **SHAPE MEMORY ALLOY ACTUATOR**

RECEIVED
NOV -6 2002
TC 2800 MAIL ROOM

Commissioner of Patents and Trademarks

Washington, D.C. 20231

11/06/2002 ADSMAN1 00000101 10056233

01 FC:1806 180.00 OP
02 FC:2201 294.00 OP
03 FC:2202 18.00 OP

PRELIMINARY AMENDMENT

Sir:

Prior to substantive action in the present application, applicant submits this Preliminary Amendment under*37 CFR 1.115* which states, in part, that a Preliminary Amendment shall be entered before the date of the First Office Action.

I. Please amend the specification as follows.

On page 1, line 5, delete '-in-part", and on line 6, after "2000", insert --- now U.S. patent no. 6,326,707, issued December 4, 2001,---.

The paragraph beginning on page 1, line 5 now reads, "This application is a continuation of application serial no. 09/566,446, filed May 8, 2000, now U.S. patent no. 6,326,707, issued December 4, 2001,for which priority is claimed."

II. Please cancel claims 1-12 without prejudice and add the following new claims:

Claim 13. (new) -- A linear actuator, including:

a plurality of sub-modules disposed in closely spaced array and adapted to undergo reciprocal translation in a first direction,;

a plurality of shape memory components, each extending generally in said first direction and connected between two adjacent sub-modules;

means for heating said shape memory components beyond the memory transition temperature to contract all of said shape memory components and urge said sub-modules to translate in said first direction, each sub-module undergoing a stroke displacement with respect to the adjacent sub-module.

Claim 14. (new) -- A linear actuator, including:

at least three sub-modules disposed in closely spaced array and adapted to undergo reciprocal translation in a first direction;

a plurality of shape memory components, each extending generally in said first direction and connected between two adjacent sub-modules;

means for heating said shape memory components beyond the memory transition temperature to contract said shape memory components and urge said sub-modules to translate in said first direction, each sub-module undergoing a stroke displacement with respect to the adjacent sub-module.

Claim 15. (new) -- A linear actuator, including:

a plurality of sub-modules disposed in closely spaced array and adapted to undergo reciprocal translation in a first direction,;

a plurality of shape memory wires, each extending generally in said first direction and connected between two adjacent sub-modules;

means for heating said shape memory wires beyond the memory transition temperature to contract said shape memory wires and urge said sub-modules to translate in said first direction, each sub-module undergoing a stroke displacement with respect to the adjacent sub-module.

Claim 16. (new) -- A linear actuator, including:

a plurality of sub-modules disposed in closely spaced array and adapted to undergo reciprocal translation in a first direction,;

a plurality of shape memory components, each extending generally in said first direction and connected between two adjacent sub-modules;

means for securing said sub-modules in said closely spaced array and permitting reciprocal movement of said sub-modules solely in said first direction;

means for heating said shape memory components beyond the memory transition temperature to contract said shape memory components and urge said sub-modules to translate in said first direction, each sub-module undergoing a stroke displacement with respect to the adjacent sub-module.

Claim 17. (new) -- A linear actuator, including:

a plurality of sub-modules disposed in closely spaced array and adapted to undergo reciprocal translation in a first direction,;

a plurality of shape memory components, each extending generally in said first direction and connected between two adjacent sub-modules;

means for heating said shape memory components beyond the memory transition temperature to contract said shape memory components and urge said sub-modules to translate in said first direction, each sub-module undergoing a stroke displacement with respect to the adjacent sub-module; and,

return means for resiliently opposing said stroke displacements of said plurality of sub-modules and translating said sub-modules retrograde with respect to said first direction.

Claim 18. (new) -- A linear actuator, including:

a plurality of sub-modules disposed in closely spaced array and adapted to undergo reciprocal translation in a first direction;

a plurality of shape memory components, each extending generally in said first direction and connected between two adjacent sub-modules;

means for heating said shape memory components beyond the memory transition temperature to contract all of said shape memory components and urge said sub-modules to translate in said first direction, each sub-module undergoing a stroke displacement with respect to the adjacent sub-module;

said shape memory components forming serial mechanical connections between said sub-modules that combine said stroke displacements of said sub-modules in additive fashion to impart a long stroke output to an output sub-module.

Claim 19. (new) -- A linear actuator, including:

a plurality of sub-modules disposed in closely spaced array and adapted to undergo reciprocal translation in a first direction;

said sub-modules each including a plate-like bar, said plate-like bars extending in said first direction in parallel, stacked relationship;

a plurality of shape memory wires, each extending generally in said first direction and connected between two adjacent plate-like bars;

means for heating said shape memory wires beyond the memory transition temperature to contract all said shape memory wires and urge said plate-like bars to translate in said first direction, each plate-like bar undergoing a stroke displacement with respect to the adjacent plate-like bar;

said shape memory wires forming serial mechanical connections between said plate-like bars that combine said stroke displacements of said plate-like bars in additive fashion to impart a long stroke output to an output sub-module.

Claim 20. (new) -- A compact, linear actuator comprising a plurality of bars arranged in close proximity adjacent to each other, and linearly movable in forward and aft directions and linearly replaceable relative to each other, and a plurality of shape memory wires each constructed of a material which contracts when heated above its memory transition temperature and arranged between each pair of adjacent bars, a first end of each wire being attached to one of the bars of the pair of bars proximate a forward end thereof and a second end of each wire

attached to the other bar of the pair of bars adjacent an aft end thereof, the wires being further arranged so that they cause movement of the bars in the forward direction when heated above the transition temperature, and means for heating the wires beyond the memory transition temperature so that the contracting wires cause movement of one of the bars in the forward direction by an amount substantially equal to the combined, relative forward movement of all bars of the plurality of bars.

Claim 21. (new) -- A linear actuator according to claim 20 including a support for the bars defining a guideway for each of the bars which guides the bars in the forward and aft directions.

Claim 22. (new) -- A linear actuator according to claim 20 including a member for anchoring a first one of the plurality of bars to the support.

Claim 23. (new) -- A linear actuator according to claim 22 wherein the member comprises a shape memory wire having a first end anchored to the support and a second end attached to the first bar.

Claim 24. (new) -- A linear actuator according to claim 21 wherein the support comprises a housing substantially encapsulating the bars.

Claim 25. (new) -- A linear actuator according to claim 24 including an opening in the housing permitting linear translational movement of a last one of the bars to an exterior of the housing.

Claim 26. (new) -- A linear actuator according to claim 20 including a structure applying a force to the bars urging the bars in the aft direction for facilitating a return of the bars to their rest position after the temperature of the wires drops below the memory transition temperature.

Claim 27. (new) -- A linear actuator according to claim 26 wherein the bars are movable between an aft, rest position and a forward extended position, and wherein the structure applies a force to the bars which decreases as the bars travel in the forward direction from their rest positions to their extended positions.

Claim 28. (new) -- A linear actuator according to claim 20 including a member maintaining the bars in close proximity to each other during movement in the forward and aft directions.

Claim 29. (new) -- A linear actuator according to claim 28 wherein the member comprises a support for the bars and guideways formed by the member along which the bars move in the forward and aft directions.

Claim 30. (new) -- A compact, linear actuator comprising a plurality of plate members stacked in close proximity on top of each other and terminating in top and bottom plate members, and an arrangement permitting the plate members to linearly move with respect to each other in forward and aft directions between an extended position and a rest position and maintaining the plates stacked one on top of the other during movements in the forward and aft directions, a plurality of shape memory wires which contract when heated to its memory transition

temperature and disposed between each pair of adjacent plate members, each wire having a forward end attached proximate a forward end of one of the plate members of the pair and an aft end attached proximate an aft end of the other one of the plate members of the pair, the wires being attached to the respective plate members so that, upon contraction of the wires, the wires cause relative movement between all plate members in the forward direction, and means for heating the wires beyond a memory transition temperature thereby to move one of the top and bottom members in a forward direction by an amount about equal to the combined amount of relative forward movement of all plate members.

Claim 31. (new) --A linear actuator according to claim 30 wherein one of the top and bottom plate members forms a reciprocating actuator member.

Claim 32. (new) --A linear actuator according to claim 30 wherein the wires are located between opposing surfaces of plate members.

Claim 33. (new) --A linear actuator according claim 30 wherein opposing surfaces of adjacent plate members touch each other.

Claim 34. (new) --A compact, linear actuator comprising a plurality of elongated bars having surfaces in mutual contact and being mounted in stacked relationship for linear, back-and-forth movement between a rest position and an extended position, a first bar defining one end of the stack of bars and a last bar of the stack defining an actuator member, a plurality of wires made of shape memory

material which contracts when heated beyond its memory transition temperature, a forward end of each wire being attached to a forward end of a bar and an aft end of each wire being attached to an aft end of the adjacent bar which is relatively closer to the actuator member, a support operatively coupled with the bars and permitting movement of and guiding the bars during back-and-forth movements between the rest and extended positions, a source of electric current coupled with the wires for intermittently subjecting the wires to an electric current which heats the wires beyond the memory transition temperature and causes a contraction of the wires to move all bars with respect to the first bar in the forward direction, whereby the last bar travels the longest distance of all bars in the forward direction when the wires are electrically heated, and an arrangement causing the bars to move in the aft direction towards the rest position when the temperature of the wires drops below the memory transition temperature.

III. Attached hereto is an Information Disclosure Statement, form SB/08, citing prior art that may be germane to the present invention. These citations were provided to applicants by a potential licensee/competitor as the product of an apparently exhaustive search of the prior art, and may therefore represent prior art relevant to the present invention. Applicant is fulfilling the duty of candor and forwarding all of these citations herewith.

Nonetheless, it is clear that none of these citations, taken singly or together, provide the basis for rejection of any of the new claims added by the present

Preliminary Amendment. The following brief comments summarize each of the citations.

US 6,218,762 Hill

A MEMS micro-actuator employs arched beams formed on or adjacent to a silicon substrate, and the beams may be deformed thermally to undergo movement. In some embodiments the beam deflections are additive. There is no use of SMA contracting elements, no plurality of sub-modules reciprocating and translating, no stroke amplification.

US 5,763,979 Mukherjee

This actuation system for controlling multiple SMA elements discloses no real mechanical structure for an actuator.

US5,685,148 Robert

An SMA wire is wound many times about two rods 3 and 6, and contracts to rotate lever 1 about shaft 2 to move plunger 9. This pulley arrangement is old, and not germane to the linear actuator mechanism of the invention.

US 5,563,466 Rennex

Microminiature actuator mechanisms are operated by electrostatic attraction and repulsion. In Fig. 22, expansive elements 180 are connected head-to-toe by connector elements 183, so that expansive motion is additive. In Fig. 23, each

stage includes the combination of an expanding element 185 and a contracting element 186. Thus Rennex is limited to actuator assemblies that employ plural <u>expansion</u> elements, with the possible addition of interspersed contracting elements. There is no displacement additive mechanism that operates using only contracting elements.

Note also that Rennex employs electrostatic attraction and repulsion as the motivating force between opposed elements, a mechanism that is inherently limited to closely spaced surfaces and small dimensions. The present invention relies on the metal phase change of SMA elements, a thermal mechanism that is better suited to larger dimensioned actuators suitable for mechanical use in buildings, vehicles, consumer devices, and the like.

<u>US 5,556,370 Maynard</u>

An endoscope is comprised of a plurality of tubular joints joined by pivot shafts, each having an SMA wire coiled around the body of opposing joint halves and adapted to rotate one half with respect to the other. This is not a linear actuator, there is no real stroke amplification, although the angular movement of the assembled joints is additive in a general way along the length of the endoscope.

<u>US 5,344,506 DeAngelis</u>

An SMA actuator is used to drive a cable cutter to sever a cable and deploy a load. This is a high force device that employs a plurality of SMA rods 250, 260,

270 that extend between movable coupling joints 216, 218. Expanding rods alternate in the arrangement with contracting rods. This arrangement is relevant in that it employs plural SMA elements in parallel array, and that the length change of each SMA element is added to the others by the mechanism.

Aside from these two points of general relevance, there are many ways in which the invention is distinguished over this reference. It is notable that DeAngelis describes a single use device, and <u>never describes nor hints that the mechanism is used more than once.</u> Indications of single use are:

- Once the cable is cut, the task is complete and the device has no further function.
- Shear pin 128 is present in all embodiments, and is used to block movement until sufficient force has built up to cleave pin 128 (and the cable). The pin 128 is not replaced, indicating again that this is a single use device.
- There is no mechanism to apply a return force to the device that would enable reciprocation.
- In col. 6, lines 6-12, DeAngelis states that the assembly must be disassembled, SMA elements recompressed, and then reassembled before reuse.

It is also significant to note that the DeAngelis two stage arrangement requires both expanding and contracting SMA elements. That is, the motive direction (expansion or contraction) of each successive SMA element must be opposite to the serially adjacent elements. If, *arguendo*, the expanding elements

were eliminated in an attempt to equal the all-contracting SMA elements of the invention, the DeAngelis stages would not be linked together, and would require a complete redesign to become operative. Thus DeAngelis cannot be construed to teach the use of contracting SMA elements exclusively; indeed, it teaches away from that concept.

Thus there are at least the following important distinguishing features of the present invention:

1) the sub-modules are adapted to undergo reciprocal translation, whereas DeAngelis has no reciprocating function;

2) the invention employs SMA elements that contract to provide motive power, whereas DeAngelis requires contraction and expansion elements, in combination. This is not merely an alternative use of equivalent elements, due to the mechanical relationships of the components. Expanding SMA elements require sufficient bending strength to deliver its own expansive force as well as the accumulated force of the other stages. Bending strength (stiffness) must be provided by some cross-sectional configuration such as an I beam, H beam, box rail, channel, or similar prior art shape. Due to the fact that SMA expansion is limited to about 5%, the SMA expansion element must be fairly long, necessitating a substantial cross-sectional beam area. The mechanism of the reference cannot be scaled down to the use of wires, due to the fact that an SMA wire cannot be made stiff enough to deliver expansive force without buckling and failing. SMA rods or beams require too much space to be useful in this type of linear actuator having closely spaced sub-modules.

3) the invention employs more than two stages.

Note in DeAngelis col. 7, lines 20 et seq., a mention of a plurality of SMA elements, which is susceptible to interpretation as implying a larger scale array of stages, rather than the two stages shown in the drawings. However, there is no mention of a plurality of coupling brackets, each of which would define a further stage, and it must be concluded that DeAngelis is merely adding multiple SMAs between the two coupling brackets. Thus DeAngelis is limited to it's literal disclosure, which is two stages.

<u>US 5,312,152 Woebkenberg</u>

This patent describes the same SMA single use actuator as US 5,344,506 to DeAngelis, who is a co-inventor here. All of the limitations and distinctions noted above regarding DeAngelis are likewise valid here.

<u>US 5,172,551 Nakajima</u>

An actuator includes a stack of a plurality of expandable chambers filled with a thermally expandable liquid, and means for heating and cooling the liquid to selectively alter the stack height. The expansion of each chamber is added to the others in a bulk effect, but there is no disclosure of a linear actuator comprised of a plurality of reciprocally translating sub-modules. Note that this mechanism employs expansion of a liquid to actuate, whereas the present invention employs contraction of SMA elements to actuate.

US 4,977,886 Takehana

A position controlling apparatus for an endoscope, in which SMA elements (e.g., coils 181, Figure 26) are used to articulate a pseudo-vertebral column in the endoscope catheter. The disclosure is predominantly sensing and control systems, not mechanical systems.

US 4,586,335 Hosoda

A linear actuator includes a cylinder and piston, and a plurality of SMA elements connected therebetween to contract and urge the piston into the cylinder against the restoring force of a helical spring. The SMA elements may comprise wires, coils, rods, combinations thereof, and a wire/pulley arrangement. It is significant that the SMA elements are disposed in parallel mechanical connections, so that there is no stroke amplification (displacement summation).

US 4,579,006 Hosoda

A force sensing apparatus for controlling and driving a SMA detects temperature or resistance and displacement to calculate SMA force. No mechanical structure.

US 3,940,935 Richardson

A positioning device for a pen-supporting arm employs an SMA contracting wire element opposed by a spring having a negative spring

characteristic. There is no linear actuator disclosure, no stroke amplification, no multiple reciprocating sub-modules.

US 2,975,307 Schroeder

A capacitive prime mover employs dielectric plates interleaved with insulating spacers to create electrostatic attraction across the stack and achieve motion and displacement. This reference uses a bulk electrostatic effect, not SMA elements, and there is no disclosure relating to linear actuator having reciprocally translating sub-modules in stroke-adding combination.

DE 195 09 177 Ziegler

A plurality of SMA wires 9 are passed about rollers 15, and thence to a large roller 17 to rotate pivot arm 1. This is not a linear actuator, and merely folds the SMA wire over a number of pulleys to provide sufficient length to achieve the desired displacement effect.

DE 4 209 815 Klawuhn

In one embodiment, a plurality of SMA wires 9 extend in parallel from a header 3 to a movable bar 10; heating the wires causes them to contract, and a link 12 from the movable bar is connected to a lever arm 13, which is pivoted to move a switch throw 5 linearly. In the other embodiment, Figs. 3 and 4, there are a plurality of pivoting bars 18b in spaced apart, staggered opposition to a plurality of pivoting bars 18a. SMA wires 9 extend from an anchor 14 to one end of the first

pivoting bar 18b, and another wire 9 extends from the other end of the first bar 18 b to one end of a bar 18a, and so forth. This mechanism uses SMA wires, and demonstrates a form of displacement amplification, in that the rotation of one pivoting bar is added to the next.

There are manifest distinctions of the present invention over this reference, such as:

1) The invention describes and claims a <u>linear</u> actuator, not a rotary actuator, having a plurality of sub-modules adapted to undergo -

2) <u>reciprocal translation</u> in a <u>first direction</u>, none of which is true of this reference. In addition,

3) the SMA components of the invention must extend in the first direction, which cannot read on this reference, where the SMA component ends are secured to rotating bars and vary in their angles in accordance with the positions of the bars.

There is no suggestion in this patent of applying stroke amplification to linearly moving stages; in fact, it shows, if anything, a coupling of pivoting bars that achieves rotational amplification, not stroke amplification.

The pivoting bars require a lot of "real estate," that is, a large area, on their mounting board: although it is fairly flat, the assembly cannot be made usefully small because of the need for open area to rotate the bars. Thus it is not in a "closely spaced array."

FR 2 730 766 Ramon/Noel

A thermal actuator includes passive elements 18 coupled between active elements 14, 16, the active elements having positive thermal coefficient of expansion and the passive element having lesser, null, or negative thermal coefficient of expansion. The excursions of the two active elements are summed. The device employs expansion only as the motive force, and does not employ SMA elements, nor does it teach a stroke amplification mechanism that operates solely with SMA contraction elements.

UK 2 334 046 Western Atlas (Reinhardt)

A borehole tractor motor includes SMA element 20 coupled to arms 16 in a lever ratio amplified manner. The legs 16 rotate outwardly to engage the borehole wall, after which further SMA contraction pushes the device downwardly. Similar to an umbrella mechanism. Although this is an SMA linear motor, it uses lever rotation to function properly, and does not teach any form of stroke amplification. This reference has no direct relationship of components to elements of the claims.

UK 2 093 589 Garness

A thermal compensation apparatus for optical systems includes a plurality of telescoping sleeves, each having an SMA coil extending thereabout and disposed to exert force against an adjacent sleeve. Each sleeve also includes a return spring arrangement having a negative return rate. The SMA coils have different threshold temperatures to gradually change the length of the assembly as

temperatures rise or fall with respect the individual threshold temperatures. The SMA elements are used in expansion as well as contraction, and the assembly cannot extend fully in one operation: each sleeve extends individually as it exceeds its threshold temperature.

<u>EPO 0 147 491 Spar Aerospace</u>

A thermal linear actuator includes a plurality of thin plates 14 and 16 in alternating array, the plates connected end to end in accordion fashion. Plates 14 have high thermal expansion, plates 16 have low thermal expansion and act as links between the plates 14. The thermal expansion motion is additive through the plate array.

There is no disclosure of using SMA elements, nor of using any materials that contract upon heating. This teaching is contrary to the claimed invention, which relies solely on contracting SMA elements. Also, the expansion members of the reference cannot be reduced to wire size without buckling when placed in expansion. Thus there is no parity between mechanisms that employ expansion elements, and those that employ contracting elements. That is, a mechanism that employs a contracting SMA element relies on the tension in the element to maintain its alignment between adjacent stages. On the contrary, expanding elements require bending strength to deliver force in compression without buckling, and bending strength requires a beam cross-section to impart stiffness. The beam cross-section dimensions are an inherent limit in reducing the actuator size to useful overall dimensions.

WO 98/08355 Northern Telecom

A digital data multiplexing arrangement that has no SMA device disclosure whatsoever.

WO 01/12985 A1 MacGregor

In Figs. 3-8, 18-20, a linear actuator employs a plurality of SMA wires connected between rigid members that translate in the same direction, so that the displacements of the rigid members are summed. Note that applicant's effective filing date is May 8, 2000, well prior to the publication date (Feb. 22, 2001), and that this published application does not designate the United States of America for coverage.

Microminiature SMA Actuator Ikuta

A gripper pincer includes two opposed jaws extending from pivoting arms, and a pair of SMA coils connected to each arm to rotate the arms and close or open the jaws. No stroke amplification, no linear actuator mechanism.

Remarks

In this Preliminary Amendment applicants have satisfied the duty of candor by citing a large body of prior art that has been submitted to applicants. In addition, new claims 13-34 have been added to the application in light of the distinctions of the present invention over the numerous citations.

The following comments are presented to point out the distinctions of the present claims over applicants' prior art citations. Of the references G1-G22 cited herewith, the disclosure closest to the present invention is the MacGregor publication, G21. However, the reference is not prior art against the present application because it was published after the effective filing date of the present application, and further because the international application does not designate the United States of America. Therefore this reference will not be further discussed below. The next closest reference are DeAngelis and Woebkenberg, G6 and G7, which describe the same SMA actuator mechanism, and will be referenced as G6.

As noted above, G6 describes an actuator mechanism that does not reciprocate. It advances to sever a cable and stops. Before it is re-used, it is disassembled, recompressed (for the expanding SMA rod), and then reassembled. Thus the stages of the reference specifically do not reciprocate. All of the claims now presented recite "a plurality of sub-modules disposed in closely spaced array and adapted to under reciprocal translation in a first direction". The reference's teaching is completely opposed to the reciprocal translation statement in all claims. This distinction alone renders the claims allowable over the G6 reference.

In addition, all the claims contain the language above as well as further distinguishing recitations over this reference in particular. Claim 13 also recites that the means for heating functions to contract <u>all</u> of the shape memory components . In direct contrast to this limitation, the G6 reference requires the use of expanding SMA components in combination with contracting SMA

components in order to link together the two stages and deliver an actuation. Thus claim 13 clearly defines the invention over this reference.

Claim 14 is a slight modification of claim 13, in that it describes an actuator having "at least three sub-modules disposed in closely spaced array and adapted to undergo reciprocal translation in a first direction". The G6 reference provides only two stages, and, although it mentions the use of additional SMA, it pointedly does not suggest using more than two stages. Thus it should be concluded that the reference does not teach the use of more than two stages, and for this additional reason claim 14 is defined over the reference.

Claim 15 differs from claim 13 primarily in that it recites the use of shape memory wires extending between adjacent sub-modules. The G6 reference utilizes SMA rods to deliver a high force output. The mechanism of the reference cannot be scaled down to the use of wires, due to the fact that a wire will buckle and fail when arranged to deliver expansive force. The reference requires at least one expansive SMA element, and therefore cannot employ SMA wire components. Thus claim 15 also defines the invention over the art.

Claim 16 contains the general recitation of claim 13, and adds means for securing the sub-modules in the closely spaced array and permitting reciprocal movement of the sub-modules solely in the first direction. In the present application, the term "closely spaced array" generally refers to the sub-modules or bars or plates disposed in stacked or nested relationship with minimal or no spacing therebetween. Once again, the reference does not suggest reciprocal

translation of the stages, and this claim language finds no counterpart in the reference. Thus claim 16 also should be allowed over the reference.

Claim 17 has the same general format, and adds return means for resiliently opposing the stroke displacements of the sub-modules and translating the sub-modules retrograde to the first direction. The G6 reference lacks this function completely, and claim 17 is clearly allowable over the reference.

Claim 18 also employs the same general format as claim 13, and specifically adds that the "shape memory components form serial mechanical connections between said sub-modules that combine said stroke displacements of said sub-modules in additive fashion to impart a long stroke output to an output sub-module." This recitation defines the invention over the G6 reference by specifying that all the SMA components contract. It goes further by describing that the SMA components link the sub-modules in serial mechanical association to combine the displacements in additive fashion and impart it to an output sub-module. The G6 reference does not provide this linkage using all-contracting components, and cannot operate using exclusively contracting elements, and claim 18 is thus defined over the reference.

Claim 19 recites the plurality of sub-modules, and specifies that each includes a plate-like bar, the bars extending in the first direction in parallel, stacked relationship. It recites SMA wires extending in the first direction and connected between adjacent bars, and that all the SMA wires are heated to contract and urge the bars to translate in the first direction. It also recites that the SMA wires form serial mechanical connections between the bars to add the stroke

displacements. The G6 reference does not have plate-like bars extending in the first (actuating) direction; rather, it has bracket ends transverse to the actuating direction. The G6 reference does not provide this linkage using all-contracting components, and cannot operate using exclusively contracting elements. Claim 19 is thus easily distinguished over the reference.

Independent claim 20 defines the invention in more explicit terms than previous claims, including SMA wires that contract when heated, the details of their connections between adjacent bars, the forward movement of the bars, and the additive displacement arrangement of the assembly. This claim and dependent claims 21-29 define the invention patentably, and are submitted in the belief that they are allowable over the art.

Independent claim 30 also recites explicit structure of the invention, including plate members stacked in close proximity on top of each other, unlike the G6 reference, for example. It also defines the fore and aft direction of the reciprocal translation of the plates, and the use of shape memory wires each disposed between adjacent plates. It specifies that the wires contract to move the plates, and that the arrangement combines the displacements of the plates. These limitations are absent in the prior art, as discussed at length above, and claim 30 (and related dependent claims 31-33) are allowable.

Independent claim 34 recites the linear actuator having elongated bars with surfaces in mutual contact, clearly setting forth the close spacing of the components and distinguishing over the G6 reference. It also recites that the bars extend back-and-forth, and the last bar in the stack is the actuator member. It

states that SMA wires connect the bars, and contract to translate the bars and drive the actuator member. These limitations clearly make this claim allowable.

It is not practical to compare each of the claims with each of the references, so it is necessary to make more general comments. It is noted that there are linear actuator devices in the prior art that have some suggestion of multiple stages coupled to add their individual movements. See, for example, references G4, G8, G16 or G18. However, these devices all employ either contracting and expanding elements combined together, or solely expanding elements combined together. There is no suggestion of a stroke additive mechanism that employs only contracting elements. The exclusive use of contracting components enables the use of thin wires, since no beam strength (stiffness) is necessary to transmit expansive forces. This in turn enables miniaturization of the actuator to a small size range because it can used thin wires without the danger of having them buckle, as is true for arrangements which employ SMA elements that expand when heated. Thus the use solely of contracting SMA wires is not merely a substitution of equivalent components, it is an important advance over the prior art which has failed to recognize this advantage.

The Klawuhn reference, G15, describes an SMA device that does use only contracting SMA wires. However, it is not a linear actuator, and it does not have a plurality of sub-modules disposed in closely spaced array and adapted to undergo reciprocal translation in a first direction. And the wires in the G15 reference do not extend in the first direction, they extend transverse to the nominal direction of the pivoting bars of the reference. Likewise, an attempt to combine the all-

contracting SMA wires of G15 with the linear stages of G6 would be inapt, due to the fact that G6 requires both expanding and contracting SMA elements to link the stages and form a cohesive operating structure.

Applicants believe that all claims now submitted for examination clearly define the invention over the best known prior art. An action on the merits is awaited.

Respectfully Submitted,

Howard Cohen

Howard Cohen
Registration No. 27,118
1105 The Alameda
Berkeley, CA 94707
510-524-7733
fax 510-558-7260

I hereby certify that this correspondence is being deposited with the U.S. Postal Service as properly posted first class mail in an envelope addressed to: Commissioner of Patents and Trademarks, Washington D.C. 20231, on

10-31-2002.

Howard Cohen

10-31-2002
date